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URBAN TRAFFIC SIGNAL CONTROL FOR FUEL ECONOMY

PART 2: EXTENSION TO SMALL CARS

by

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Division of Mechanical Engineering

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URBAN TRAFFIC SIGNAL CONTROL FOR FUEL ECONOMY

PART 2: EXTENSION TO SMALL CARS

ÉCONOMIE D'ESSENCE GRÂCE À LA COMMANDE DES FEUX DE CIRCULATION EN ZONE URBAINE

PARTIE 2: APPLICATION AUX VÉHICULES DE PETITE CYLINDRÉE

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SUMMARY

Use of a small car's characteristics in a simulation program utilizing velocity profiles obtained in a traffic study by the Metropolitan Toronto Roads and Traffic Department and the Engine Laboratory at the National Research Council Canada has shown that trends shown in fuel consumption in NRC, Division of Mechanical Engineering Report No. ME-247 are similar for a small-engined vehicle.

NRC, DME Report No. ME-247 showed that under the TRANSYT timing plan, vehicles encountered fewer stops, saved time and used a slightly smaller amount of fuel than under the existing timing plan. In the above mentioned report a large vehicle's fuel consumption was calculated using a computer model of the vehicle which used velocity profiles obtained from an instrumented "floating" car.

RÉSUMÉ

L'utilisation des caractéristiques d'une petite voiture dans le cadre d'un programme de simulation basé sur les profils de vitesses de l'étude sur la circulation menée par le Metropolitan Toronto Roads and Traffic Department (service des routes et de la circulation de la ville de Toronto) et le Laboratoire des moteurs du Conseil national de recherches Canada a démontré que les données de consommation d'essence présentées dans le rapport ME-247 du CNRC, Division de génie mécanique valent pour les petites cylindrées.

Selon le rapport ME-247 du CNRC, le plan de synchronisation de la circulation (TRANSYT) élimine certains arrêts, raccourcit les temps de parcours et favorise une légère économie d'essence comparativement au plan en vigueur. Le rapport mentionne également que la consommation d'un gros véhicule a été calculée à l'aide d'un modèle informatique mis au point à partir des profils de vitesses obtenus d'un véhicule expérimental roulant en douceur et se mêlant aux autres véhicules.

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PART 2: EXTENSION TO SMALL CARS

1.0 INTRODUCTION

This report is a follow-on to National Research Council, Division of Mechanical Engineering Report No. ME-247, (Ref. 1) in which it was recommended that a small car's characteristics be used in the Vehicle Simulator computer program (Ref. 2) to verify that the trends found in fuel consumption were similar to those of the large vehicle originally used.

2.0 VEHICLE DATA

Several North American auto manufacturers were helpful in answering requests for various engine performance maps, inertias, vehicle and component weights, drag factors, dimensions, efficiencies and other data. Unfortunately, the form of most of the submitted data was not readily enterable into the Vehicle Simulation program. Because of the design of the table look-ups in the program, performance maps having islands had to be replotted with a change of variables to restructure the plot into a family of non-overlapping curves. Calculation of intermediate values was also required to fill out maps so that there were values for regularly stepped rpms.

In some cases there were no data available. Here, either the original large vehicle data set was used or a value was scaled from various given values in Reference 2 in relation to recently acquired data from the auto manufacturers. The resulting data set is not a complete description of a particular production car but has general characteristics of a typical vehicle in the 1315 kg (2900 lb) range. The input data was considered proprietary by the various manufacturers and may not be released.

3.0 PREPARATION OF VEHICLE DATA SET

The following will describe the manipulations made to get the data in the form of the original Vehicle Simulator input data set outlined on page 139 and page 193 of Reference 2(b). In all cases, data was plotted with an X-Y plotter to check for irregularities and errors.

3.1 Throttle Map

Available data were in the form of torque versus percent throttle opening for a given speed. A torque value was interpolated at every 10% point of throttle opening. Then a plot was made of torque versus rpm with lines of constant throttle opening. Straight line extrapolation was used to get torque values at idle speed.

3.2 Engine Vacuum Map

Data were given in the form of vacuum versus torque for a given speed. Vacuum values were interpolated at 10 ft-lb torque intervals and normalized. A plot was made of vacuum versus rpm with lines of constant torque.

3.3 Horsepower and BSFC Maps

Additional constant rpm lines at 2500 rpm intervals were interpolated within the plot of fuel flow versus torque at constant rpm. These constant rpm lines were extrapolated to −20 ft-lb torque to account for decelerations. Tables were constructed of torque versus fuel flow for each required rpm. Then fuel flow values were interpolated for each 5 ft-lb interval and calculations made for both bhp and bsfc. Note that in the bsfc map the first column is the fuel rate given directly in lb/hr. Changes were made to the engine speed indices in the subroutine RIXON to make them compatible with the new data set.

3.4 Shift Points

Manufacturer's rpm data for 1-2 and 2-3 upshifts as well as 3-2 downshifts for each one inch of engine manifold vacuum were used directly.

3.5 Transmission Efficiency Coefficients

Gear efficiency is a function of load and rpm. Since manufacturers only provided data in the form of rpm versus gear efficiencies it was decided to use the original given data set which also took loading into account.

3.6 Gear Efficiency Index

This index indicates which gear is to be used for the gear efficiency calculation and is the same as the original data set.

3.7 Gear Ratios

These are the transmission gear ratios.

3.8 Accessory Load

It was assumed that power test data for the original engine included the accessories at test time since they were not included as an accessory load in the data set. Accessory load was included for the small vehicle since the engine characteristics were for the bare engine. The load is made up of alternator, fan and power-steering losses.

3.9 Size Factor

The size factor as a function of speed ratio was not used directly. See page 12 of Reference 2(b). A dummy data set was entered. See later heading "Table of Square of the Inverse Size Factor".

3.10 Measured Drive Shaft Speeds

To account for tire diameter growth with speed a table of driveshaft speeds measured experimentally at 10 mph increments was required. In the small car's case, due to lack of manufacturer's data, these were estimated by using the percentage decrease in rpm determined from the original data set applied to the calculated driveshaft speed.

3.11 Road Load

Road load data were not used because the option within the program to use the road load equation had been selected. This option allows specification of frontal area, drag coefficient, tire rolling friction, grade and vehicle mass. See page 131 of Reference 2(b).

3.12 Length of Drive Cycle and Cycle Profile

The EPA urban driving cycle was used in the original data set. Here, individual floating car velocity profiles were used.

3.13 Other Data

The following are other vehicle/engine characteristics grouped in the line entry format of the original data set.

Item	Comments
minimum torque	— for probability tables
maximum torque	— for probability tables
torque increment	— for probability tables
minimum engine speed	
maximum engine speed	
engine speed interval	— in original data set but not listed on page 140 of Reference 2(b)
engine inertia	
maximum torque	
maximum vacuum	
first gear ratio	
inertial mass of vehicle	
frontal area	
brake constant	
drag coefficient	
vehicle mass	
rolling friction coefficient	— used values of original data set
mass on drive wheels	— use of "percent" mass as listed on page 140 of Reference 2(b) is incorrect
tire rolling radius	
air pressure	— used values of original data set
air temperature	— used values of original data set
rear axle ratio	— used values of original data set
coefficient of maximum tire friction	— used values of original data set
sliding coefficient of tire friction	— used values of original data set
wheel base	
height of vehicle centre of gravity	
tire coulomb friction coefficient	— used values of original data set
polar moment of torque converter turbine	— estimated
polar moment of transmission third gear	— estimated, incorrectly labelled see page 136 of Reference 2(b)
polar moment of rear axle gears	
polar moment of tires and wheels	
engine scale factor	— used values of original data set
fuel weight/U.S. gallon	— used values of original data set
idle setting	— used values of original data set
automatic drive minimum lead time	— used values of original data set
length of shift	— used values of original data set
time between shifts	— used values of original data set
gain for VEDYN	— used values of original data set

number of clock pulses between printouts	— used values of original data set
print control	— used values of original data set
road load calculation control	— used values of original data set
front pump torque indicator	— in original data set but not listed on page 142 of Reference 2(b)

3.14 Table of Torque Ratios

From the plot of torque ratio versus speed ratio, torque ratios were read for two different speed ratio scales. These were:

(a) for speed ratios from 0 to 0.8 having a step size of 0.1, and

(b) greater than 0.8 having a step size of 0.01.

3.15 Table of Square of the Inverse Size Factor

The values are used in determining engine torque at the flywheel by dividing the engine speed squared by the size factor squared. Manufacturer's data of torque capacity were available only in the range of 0 to 0.973 speed ratio. A least squares curve fit was made of this data and intermediate values were calculated. Then, the square of the inverse of these values was determined. For speed ratios greater than 1, where the car is driving the engine, the original data set values of inverse size factor squared were used.

Throttle Pressure Constant	— used values of original data set
Throttle Pressure Proportionality Constant	— used values of original data set

3.16 Front Pump Torque

The original data set was used. Note that the middle figure on page 36 of Reference 2(b) should be set up as line pressure versus throttle pressure with lines of constant driveshaft rpm.

3.17 Transmission Line Pressure

The original data were used with the following changes to prevent the curves of driveshaft rpm from crossing.

Throttle Pressure	Driveshaft rpm	Transmission Line Pressure Original Value	Transmission Line Pressure New Value
20	1900	62	60
38	0	119	115
44	1500	83	80
50	1200	85	88
52	500	147	127
60	2100	83	85

Run Number — omitted
Print Controls — all changed to 1

3.18 Fuel Consumption Map

Manufacturer's data for fuel flow versus torque were extrapolated to −20 ft-lb to account for decelerations.

3.19 Emissions Maps — NOX, CO, HC

In all cases the original data were used. They were not checked for irregularities.

4.0 FUEL CONSUMPTION CALCULATIONS

As a check on the small car's data set's validity, the Vehicle Simulator program (Ref. 2) was run with the EPA driving cycle velocity profile. The resulting fuel consumption was within 4% of the closest model year's data published by Transport Canada.

The floating car velocity profiles, determined previously for March 8th and 9th, 1979, were used in place of the EPA driving cycle in the Vehicle Simulator program to calculate fuel consumption.

5.0 RESULTS

Figures 1, 2 and 3 show a comparison of the original large car's fuel consumption determined in Reference 1 and the small car's fuel consumption.

From the figures we see that for all cases the small car follows the same trends in fuel consumption as the large car.

6.0 CONCLUSIONS

(1) Trends in fuel consumption shown in Reference 1 are applicable to any spark-ignition engined vehicle.

(2) The percentage of fuel saved by using TRANSYT will be higher than 2.2% when using the small car.

7.0 REFERENCES

1. Messenger, G.S., Richardson, D.B., Graefe, P.W.U., Mufti, I.H. — *Urban Traffic Signal Control for Fuel Economy.* NRC, DME Report ME-247, National Research Council Canada, 1980.

2. (a) Beachley, N.H. et al — *Increased Fuel Economy in Transportation Systems by Use of Energy Management.* Vol. 1 — General Results and Discussion, PB-240 220, Wisconsin University.

(b) Beachley, N.H., Frank, A.A. — *Increased Fuel Economy in Transportation Systems by Use of Energy Management.* Vol. II — Digital Automotive Propulsion Simulator Programs and Description, DOT-TST-75-2.

(c) Beachley, N.H., Frank, A.A. — *Increased Fuel Economy in Transportation Systems by Use of Energy Management.* Second Year Program, Final Report, DOT-TST-76-57, December 1975.

(d) Beachley, N.H., Frank, A.A. — *Increased Fuel Economy in Transportation Systems by Use of Energy Management.* Third Year Program, Final Report, DOT-TST-77-21, 1976.

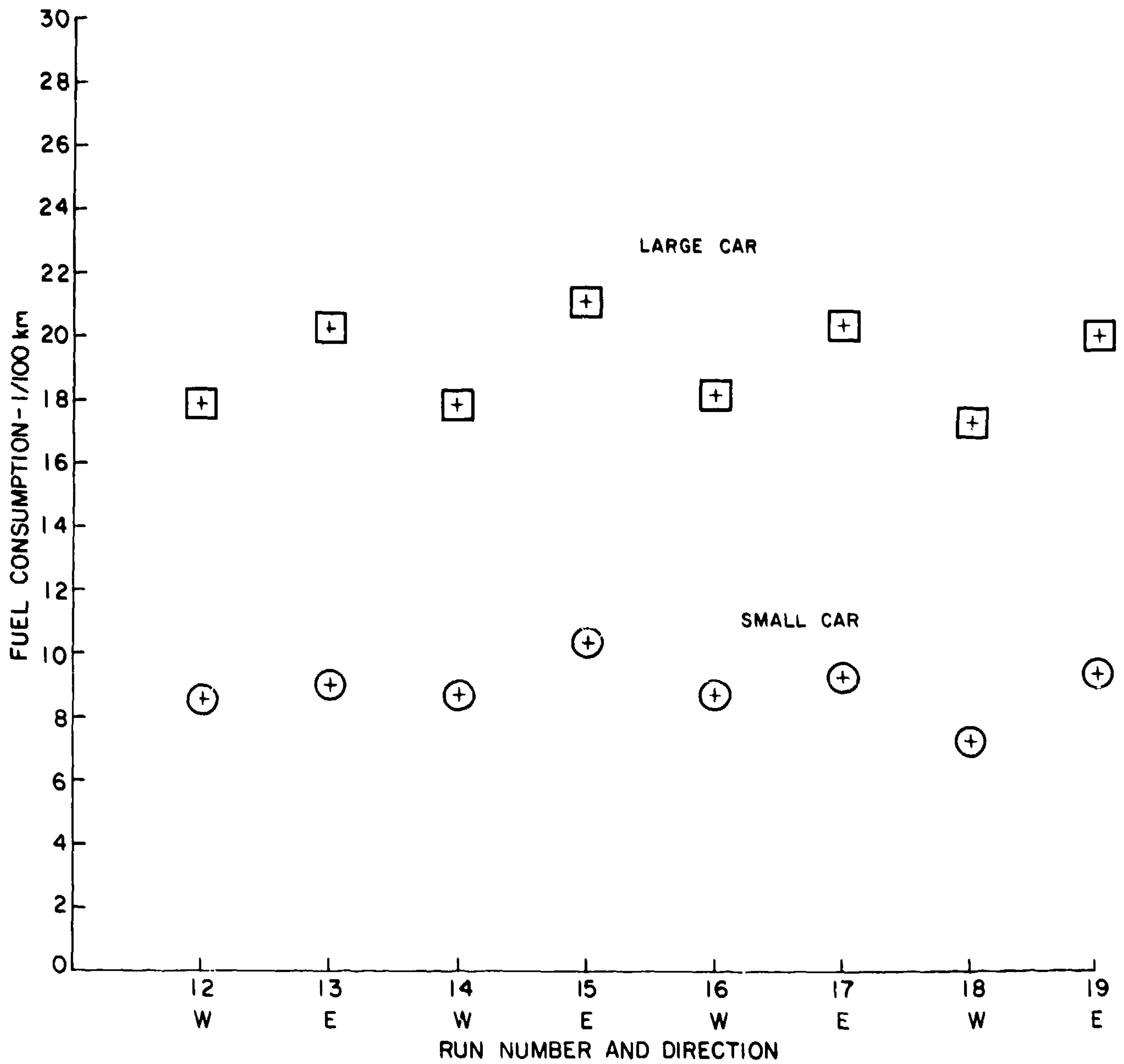

FIG. 1: FUEL ECONOMY COMPARISON FOR TRANSYT OFFPEAK RUNS OF MARCH 8, 1979

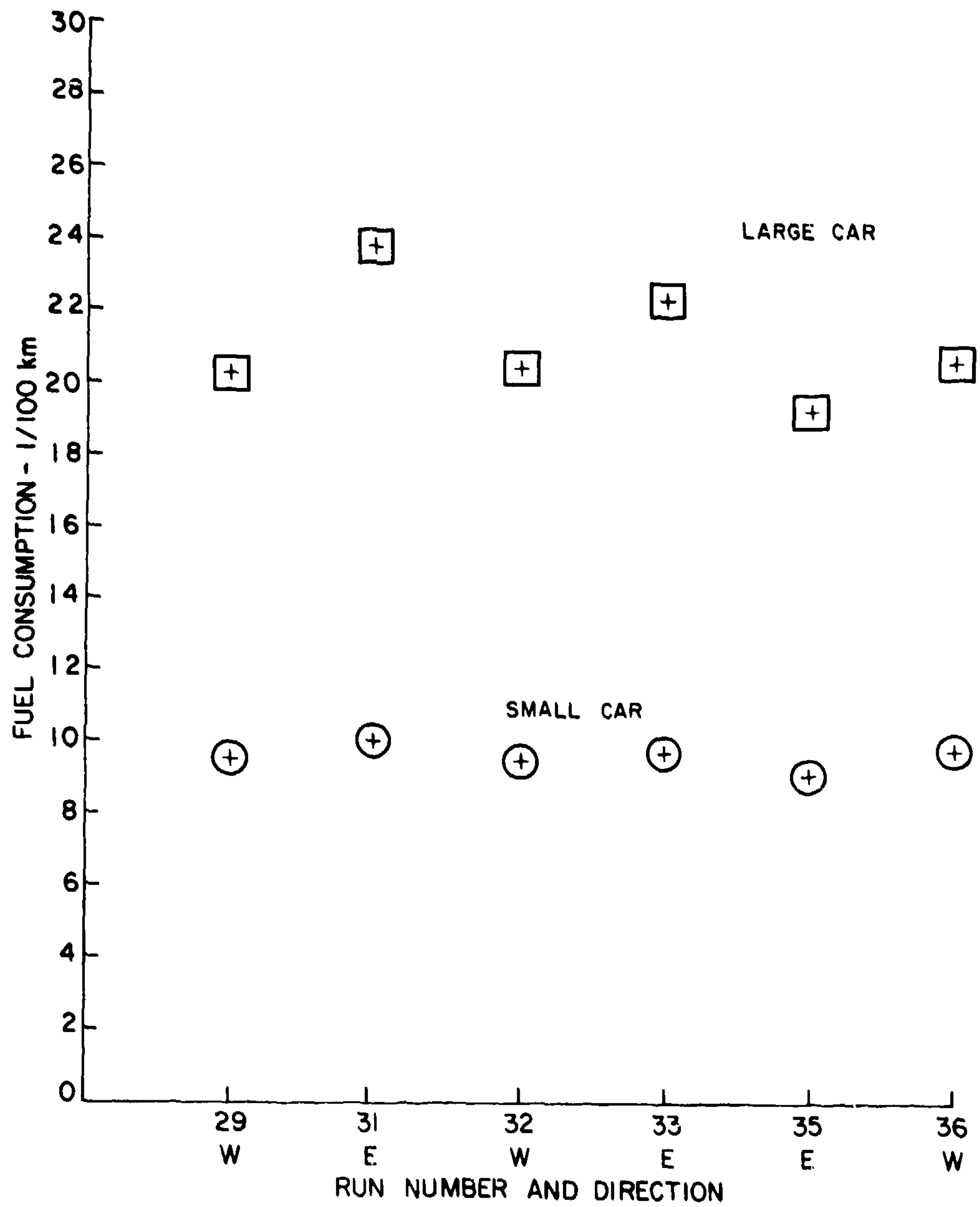

FIG. 2: FUEL ECONOMY COMPARISON FOR TRANSYT EVENING RUNS OF MARCH 8, 1979

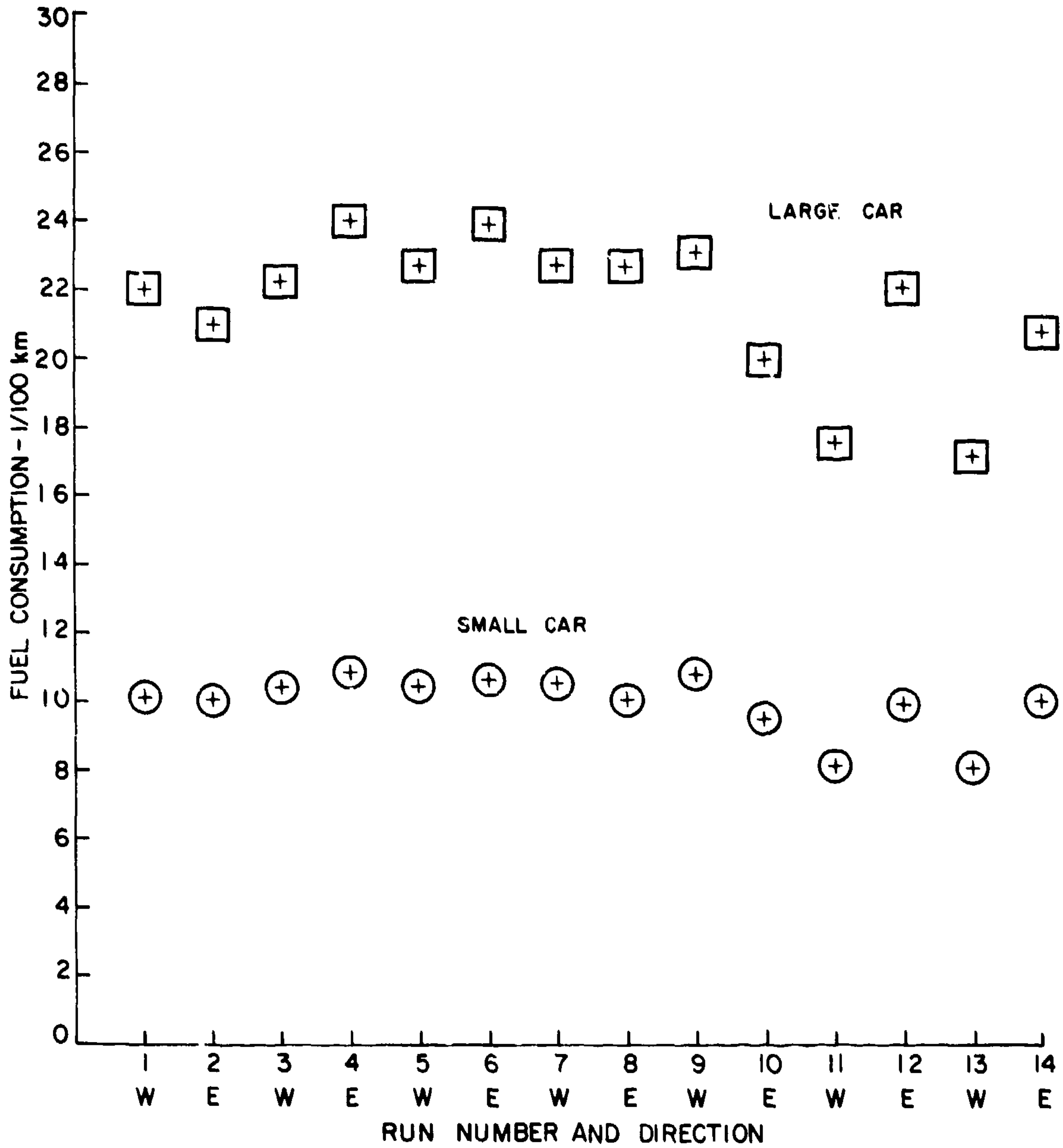

FIG. 3: FUEL ECONOMY COMPARISON FOR TRANSYT MORNING RUNS OF MARCH 9, 1979

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UNCLASSIFIED

1. Traffic signs and signals.
2. Automobiles — Fuel consumption.

I. Messenger, G.S
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